TDM 2 helps diagnose a crack on a charge gas compressor

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Aerial view of Petroquimica União S.A., Santo André, São Paulo, Brazil.

Petroquimica União S.A. (PQU) is a petrochemical plant located in Santo André, São Paulo, Brazil, that produces basic petrochemicals such as ethylene, propylene, butadiene, benzene, etc. These chemicals are raw materials for second and third generation industries, and are further transformed into many plastic products.

The machine train

GB-201, a 32,000 hp centrifugal compressor operating at the beginning of the process line, compresses a mixture of gases, called "charge gas," from the naphtha cracking furnaces. There are five compressor stages contained in three casings: low, medium, and high pressure.

The couplings are gear type, so the power is transmitted between rotors by gear teeth. Small axial displacements, due to load variation and thermal expan-

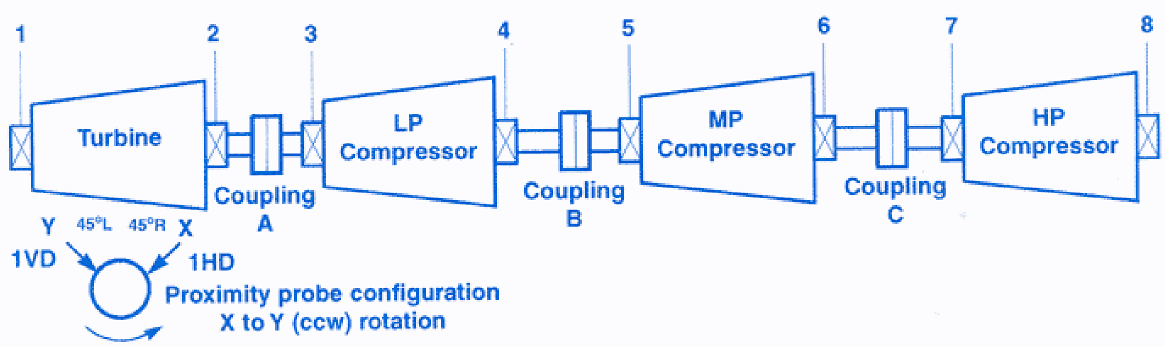


Figure 1
Machine train diagram.

sion, as well as residual misalignment, are absorbed by the couplings.

Online vibration monitoring system

The operational reliability of GB-201 is essential for the process, so PQU is continuously investing in systems to monitor the condition of this and other critical machines. In 1994, the GB-201 vibration monitoring system was modernized. The installation included a Bently Nevada 3300 Monitoring System and Transient Data Manager®2 (TDM2), a computerized machinery data management system.

This system allows for simultaneous and continuous data collection from all sensors. Data is periodically sent to a remote computer, where all vibration characteristics may be stored and analyzed during steady state or transient (startup/shutdown) operation. The system generates plots that include:

- Orbits and waveforms (direct and filtered)
- Spectrum & spectrum cascade
- Bode and polar
- Trends of overall and filtered signals, including phase lag angle
- Shaft centerline position

Occurrences

After the last overhaul in 1994, compressor vibration levels had been quite steady and acceptable. However, in late December 1995 and early January 1996, the plant experienced two shutdowns due to operational problems. The compressor was first stopped and then had its speed reduced. After these events, a sudden change was observed in overall vibration levels (Figure 2) in bearing #4.

The problem was diagnosed as a coupling B lockup because the vibration changes were sudden. There was evidence of poor coupling lubrication and excess water, probably due to leakage in the turbine seals. It was recommended that a close watch be maintained. If vibration levels suddenly increased, the machine would be shut down and started up again. The procedure was to attempt a "release" of the coupling, through the axial displacement of shafts during the shutdown and startup.

The TDM2 system made it possible to better evaluate the characteristics of another event in March 1996. The system helped identify the real cause of the sudden increase in vibration and avoid a possible catastrophic failure.

Crack diagnosis

The observation of vibration trends after January 1996, showed a continuous increase of 1X vibration in bearing #2, but with a steady phase lag angle. The overall vibration level stabilized at

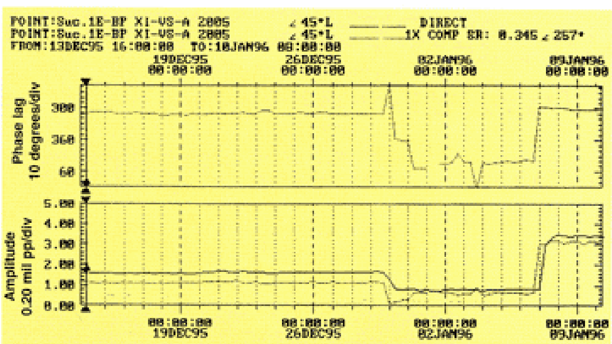


Figure 2
Bearing #4 vibration trend plot (1X) between 13 December 1995 and 10 January 1996.

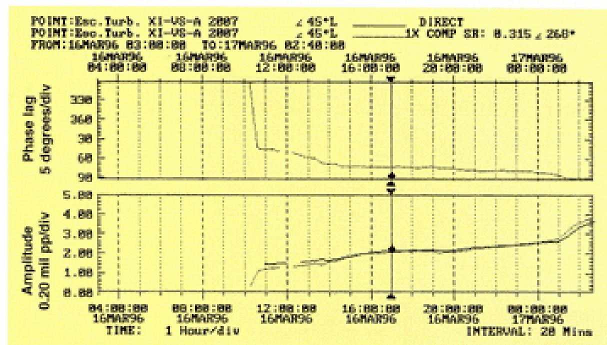


Figure 3
Bearing #2 vibration trend plot (1X). 16 to 17 March 1996.

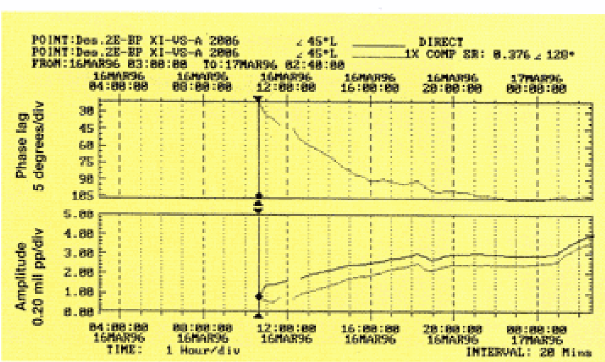


Figure 4
Bearing #3 vibration trend plot (1X). 16 to 17 March 1996.

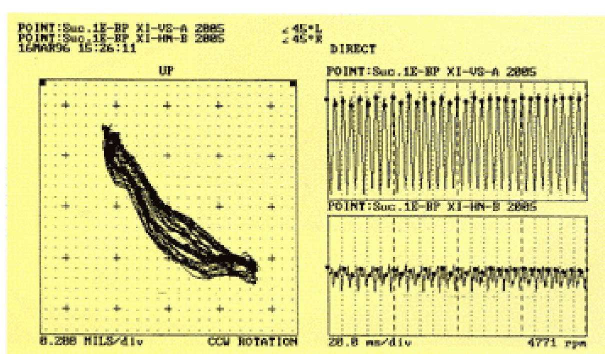


Figure 5
Bearing #4 orbit/timebase plot. 16 March 1996.

approximately 25µm (1.0 mil), and no further action was taken.

On March 16th, however, after a boiler shutdown caused an unexpected steam supply upset, fast vibration changes were observed at bearings #2, #3, and #4. At first, we assumed it was another coupling lockup and tried to release it by varying the compressor load and speed. The vibration levels increased, however, and exhibited the following characteristics:

- Predominant 1X vibration, continuously increasing.
- Continuous 1X vibration phase shift (Figures 3 and 4).
- 2X vibration at bearings #2 and #3, suggesting shaft stiffness asymmetry associated with a constant radial load.
- Banana-shaped orbit at bearing #4 (Figure 5), indicating excessive load, possibly due to gross misalignment or coupling lockup, due to poor lubrication.

The diagnosis (based on this data and a history of shaft cracks in this machine) was that there was a crack in the rotor of the compressor low pressure stage. (The low pressure compressor shaft had been replaced twice before, in 1989 and 1992, due to cracks. Both times, these cracks occurred in the keyway of the coupling hub. A hydraulically-assembled, diaphragm coupling had been installed in July 1996 to alleviate this problem.) The plant was then shut down for the necessary inspection and maintenance.

Inspection

The inspection did find a crack, but in a different component, coupling A. There was a crack through nearly 60% of the coupling section (Figure 6 and 7). A fracture analysis carried out on coupling A showed that the crack was due to fatigue, starting at three different spots.

Coupling B lockup was also confirmed, due to a large amount of oil sludge inside. The same condition was found in couplings A and C.

Root cause analysis

Further evaluation lead to the following conclusions:

- Lubrication oil was contaminated with water from a turbine seal leakage, producing oil sludge.
- There was sludge build-up around the coupling teeth, due to centrifugal forces.
- The coupling had locked up and began to act as a rigid body, unable to compensate for the residual misalignment.
- The coupling failed, due to fatigue caused by cyclic forces.

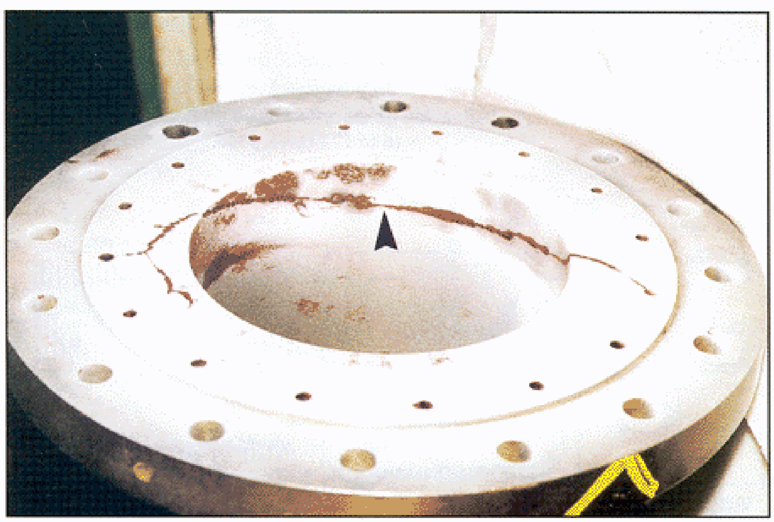
Conclusion

The information lead to two straightforward conclusions:

- A major failure was avoided because the right decision was taken, based on high-level, readily available information.
- The Bently Nevada TDM2 System was essential in providing engineers both appropriate and accurate information so they could identify the problem. ■

Editor's Note: Two of the main shaft crack symptoms are 1X vibration change and phase shift. Note that after 20:00, 16 Mar 96, (Figures 3 and 4) the phase remained quite constant. One cause of the continuous phase shift during a shaft crack is the change in the radial direction of the lower shaft stiffness, as the crack propagates. It was already getting close to 50% of the coupling section, so the direction of lower shaft stiffness remained about the same. It is reasonable to conclude that, when the phase stopped shifting, the crack process did not stop. In this case, the crack reached 60% of the coupling section.

Photos courtesy of Petroquimica União S.A.



Figures 6 and 7
Internal and external view of cracked coupling. Arrow indicates location of the crack.